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Mann Gulch Fire: A Race That Couldn't Be Won

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RESEARCH SUMMARY

The Mann Gulch fire, which overran 16 firefighters in 1949, is analyzed to show its probable movement with respect to the crew. The firefighters were smokejumpers who had parachuted near the fire on August 5, 1949. While they were moving to a safer location, the fire blocked their route. Three survived, the foreman who ignited an escape fire into which he tried to move his crew, and two firefighters who found a route to safety. Considerable controversy has centered around the probable behavior of the fire and the actions of the crew members and their foreman. Modern safety techniques used by 73 firefighters who escaped injury after being trapped on the Butte Fire in 1985 are described for comparison.

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INTRODUCTION

On August 5, 1949, a wildfire overran 16 firefighters in Mann Gulch on the Helena National Forest in Montana. Only three survived—the foreman and two members of an 18-man smokejumper crew that had parachuted into a small valley or gulch near the fire. These deaths were a shocking loss to the firefighters' families and friends. The tragedy was also a severe blow to the Forest Service, which had not experienced a fatality during a decade of smokejumping and was extremely proud of its elite firefighters. Repercussions from this incident were severe and long lasting.

In 1979, some 38 years after the Mann Gulch fire, author Norman Maclean contacted the Intermountain Fire Sciences Laboratory (IFSL) to help clarify the fire's behavior for a book he was writing about the tragedy. Maclean, who died in 1990, is well known as author of "A River Runs Through It." His second and final book, "Young Men and Fire," was published in 1992. Maclean taught at the University of Chicago, but spent his summers at Seeley Lake, MT, near his boyhood home in Missoula. His research uncovered conflicting stories of how the fire had overrun the firefighters. When Maclean learned that Frank Albini and I were developing methods to predict fire behavior, he asked if we could use the same methods to reconstruct the behavior of the fire that caught the firefighters at Mann Gulch.

Initially, I was reluctant to comply with his request because of the controversy surrounding the fire and my desire not to reopen emotional wounds. But the Forest Service, U.S. Department of Agriculture, Fire Laboratory at Missoula was conceived in the aftermath of the Mann Gulch fire. It seemed only right that we use the results of our research to help explain the complicated interactions of fuels, weather, and topography that produced such a tragedy.

Several questions about the fire had never been resolved:

- How did the fire, which was burning on a ridge when the crew landed, get below them at the mouth of the gulch?
- What was their position relative to the fire as it progressed?
- Why couldn't they escape?
- Did the escape fire ignited by the crew foreman overtake his own crew?

This paper is not intended to be a complete account of the events surrounding the Mann Gulch fire—Maclean provides such an account in his book, "Young Men and Fire." Rather, this paper examines the probable behavior of the fire and the movements of the crew during the last 20 min of the tragedy. The analysis is a reconstruction of what probably happened. Even though events late in the story appear to be worked out precisely, they cannot be verified and must be taken for what they are—reconstructed estimates.

The Mann Gulch fire had serious consequences for the Forest Service and its research branch. While in Mann Gulch to investigate the fire during the fall of 1949, Harry Gisborne, the pioneer fire scientist in the Northern Rockies, suffered a heart attack and died. Jack Barrows, who succeeded Gisborne, was directed to expedite research on fire behavior. He championed modern scientific research, establishing the Northern Forest Fire Laboratory (now the Intermountain Fire Sciences Laboratory) at Missoula in 1960.

ANALYZING FIRE BEHAVIOR

Analysis of fire behavior requires data on fuels, weather, topography, and the fire situation. Fortunately, Laird Robinson, a former smokejumper, teamed up with Maclean to learn as much as possible about the Mann Gulch fire. They persuaded the two living crew members, Robert Sallee and Walter Rumsey, to join them at Mann Gulch to reconstruct the final minutes of the tragedy. This information, coupled with their search of the archives and Robinson's knowledge of the site, provided the data used to reconstruct the fire behavior and the movements of the crew.

For those readers who wonder how it is even remotely possible to reconstruct these events, five types of information make it possible:

1. The location of the crew's movements and actions were recorded; the distances between significant actions were checked and measured by Maclean and Robinson.
2. The crew's foreman survived; his testimony during the initial investigation provided estimates of the fire's position with respect to the crew at significant moments.
3. Archived weather data and site maps were available.

4. Survivors Sallee and Rumsey recalled the types of vegetation cover they were moving through.

5. Calculations of the fire's approximate rate of spread along sections of the route were integrated with known distances and times to estimate the rate at which the crew traveled.

The fire's rate of spread, its intensity, and its flame length were calculated by using mathematical models developed from a combination of laboratory fire experiments and field data that were programmed for use by fire analysts in the field (Rothermel 1983). The initial calculations, made with the fire behavior chip developed for the TI-59 calculator (Burgan 1979), were verified with the BEHAVE computer program (Andrews 1986).

THE SCENARIO

The Mann Gulch fire was spotted at 12:25 p.m. on August 5, 1949, a very hot and windy day. The fire was in the Gates of the Mountains Wild Area (now the Gates of the Mountains Wilderness) just east of the Missouri River, 20 mi north of Helena, MT. Temperatures that day reached 97 °F in Helena. The fire started near the top of a ridge between Mann Gulch and Meriwether Canyon. Mann Gulch is a minor drainage, leading into the Missouri River from the east. It is funnel shaped, narrowing to a width of one-fourth mi at the river. The highest flanking ridge, where the fire started, is on the south side of the drainage between Mann Gulch and Meriwether Canyon. The ridge on the north side of the drainage, where the fire overran the crew, is not as high as the ridge to the south.

Vegetation on the north side of Mann Gulch was mature 60- to more than 100-yr-old ponderosa pine. The south side was covered with 15- to 50-yr-old Douglas-fir, mixed with mature ponderosa pine and some mature juniper. Fronting the river was a stand of 60- to more than 80-yr-old Douglas-fir. Mixed pine and fir grew in the bottom of the gulch.

A distinct moisture gradient is evident in the gulch; the lower slopes receive more moisture than the upper slopes. This influences the vegetation found in the understory beneath the forest canopy. At the time of the fire, lower elevations had heavier undergrowth, which gave way to scattered timber and grass in the drier areas farther up the gulch.

Access to this roadless area is difficult. Therefore, smokejumpers were called when the fire was discovered. One of the basic tenets of fire fighting is to reach a fire quickly. Then it can be attacked while it is still small. Smokejumpers are very effective at reaching a fire quickly because they travel by airplane and use parachutes to land near the fire.

In this instance, the smokejumper crew was dispatched from Missoula, MT, a little over 100 mi west of the fire. The jump, completed between 3:50 and 4:10 p.m., was considered routine by the foreman, R. Wagner Dodge, and the jumpmaster, Earl Cooley. The fire's size and location and the area where the jumpers landed are shown in figure 1. The cargo drop did not go smoothly; the plane, a twin engine DC-3, encountered heavy turbulence at normal drop altitude and was forced to climb before dropping the remaining cargo. Fire-fighting gear was scattered and the crew's radio was broken. By the time the jumpers gathered their gear, it was nearly 5 p.m. They did not feel the fire threatened them then. Surviving crew member Sallee stated in the official report of the incident:

> I took a look at the fire and decided it wasn't bad. It was burning on top of the ridge and I thought it would continue on up the ridge. I thought it probably wouldn't burn much more that night because it was the end of the burning period (for that day) and it looked like it would have to burn down across a little saddle before it went uphill any more.

While getting the crew and equipment organized, foreman Dodge heard someone shouting near the fire. He instructed squad leader William Hellman to equip the crew and lead them down the north side of Mann Gulch toward the Missouri River while Dodge went on ahead to see who was shouting. Near the top of the ridge close to the head of the fire, Dodge met James Harrison, a recreation and fire prevention guard from the Helena National Forest. Harrison, based at nearby Meriwether Campground, had been the first to spot the fire and had been trying to keep it from crossing into Meriwether Canyon while he awaited help. The fire was still moving northeast along the ridge between Mann Gulch and Meriwether Canyon. Dodge decided the ridge was not the safest place to attack the fire, so he and Harrison did not stay there. After a quick lunch they caught up with Hellman and the crew who were traversing the slope, heading down the gulch toward the Missouri River. The smokejumpers believed they were going to attack the fire in another location, certainly a safer location that would be on the upwind side of the fire, near the river.

Dodge had a clear view of the fire and could see it was burning more rapidly than before. In Helena, the wind had been blowing from the north and east at 6 to 8 mi/h that afternoon. At 3:30 p.m. the wind switched to the south, increased to 24 mi/h, and continued to blow strongly from the south at 14 to 22 mi/h. Because of the orientation of the canyons and ridges, a strong southerly wind would create extreme turbulence at the mouth of Mann Gulch, producing strong winds that would blow up the gulch toward the crew. At about 5 p.m. Canyon Ferry District Ranger Robert Jansson had reached the mouth of Mann Gulch by boat and was attempting to walk up the gulch to reach the smokejumpers. He estimated the wind at Mann Gulch to be between 20 and 30 mi/h with gusts to 40 mi/h,

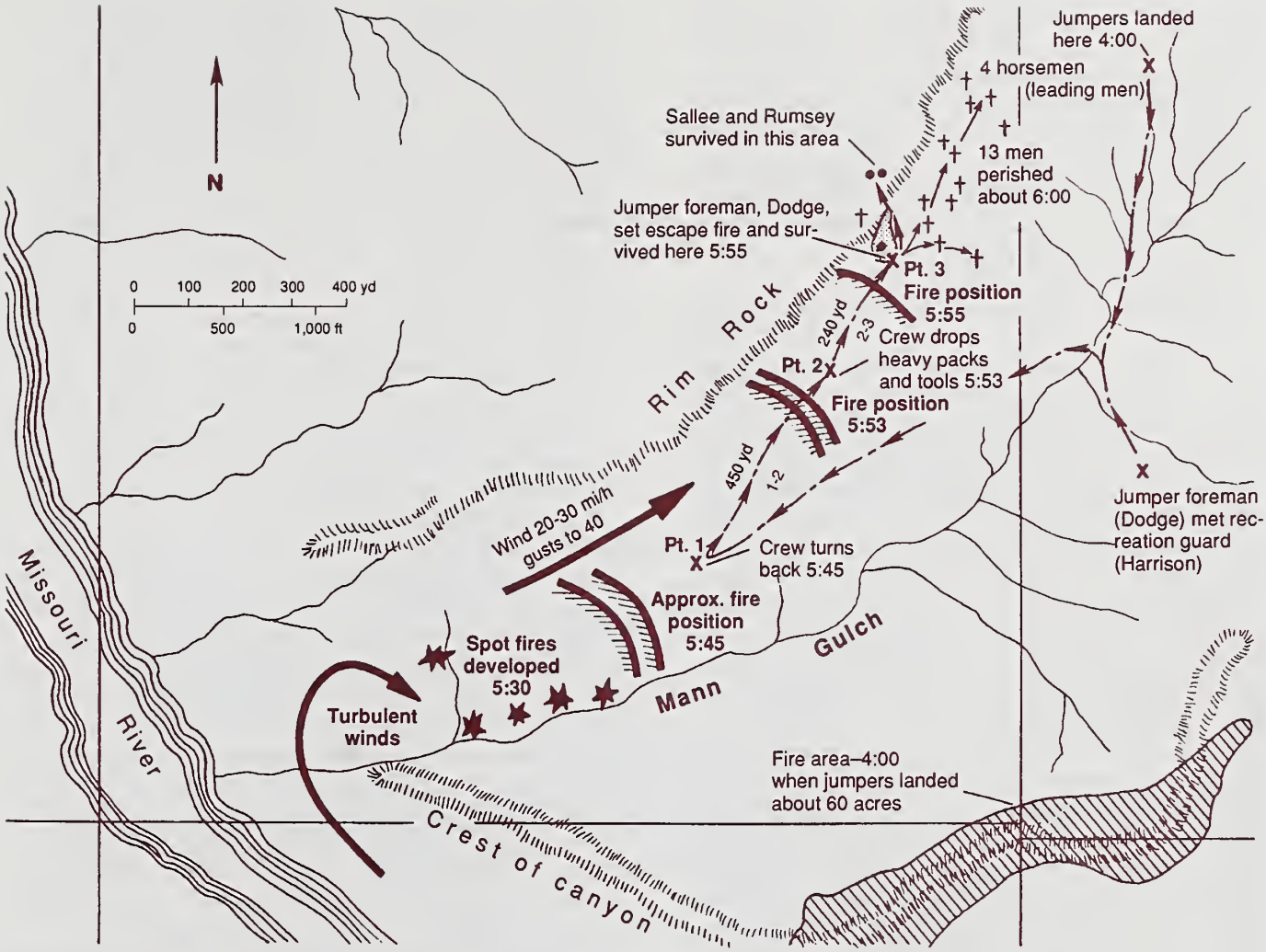

Figure 1—Map of Mann Gulch illustrating the movement of the crew and the position of the fire as it approached the crew at points (pt.) 1, 2, and 3.

much stronger than recorded at Helena. Consequently, as the crew proceeded down the gulch, they were walking into a strong headwind.

Foreman Dodge and recreation guard Harrison overtook the crew at about 5:40 p.m. Survivors Sallee and Rumsey both said the crew was not worried about safety, but Sallee thought he heard Dodge say something about the thicket of ponderosa pine and Douglas-fir they were in being a death trap.

They continued down the canyon for another 5 min, covering about 400 yd, when they saw fire blocking their route to the river. Firebrands from the main fire had started spot fires in the timber ahead of them. These fires were rapidly becoming more intense.

During discussions after the tragedy that followed, fire experts were particularly concerned with understanding how the fire got from the ridge high on the south side of Mann Gulch to the mouth of the gulch and later to the north side. To this day, two opinions persist. One is that downdrafts of a small local thunderstorm blew the fire off the ridge into the mouth of the canyon. This idea is supported by motion picture films (now lost) taken by a Forest Service photographer from the same aircraft that dropped Dodge's crew. According to Jack Barrows (1980), who viewed these films many times, "They clearly showed rather intense downdrafts." Barrows, who said he visited the site with survivors Dodge and Sallee, concluded that the thunder cell downdraft was an important factor in throwing firebrands to the mouth of Mann Gulch. Other fire experts suspected whirlwinds may have spread the fire. Fire whirls and downdrafts from thunderstorms or the fire's convection column can occur together. Harry Gisborne, then director of fire research at the Northern Rocky Mountain Research Station, notes in the margin of an official report that fire whirls formed at the mouth of Mann Gulch. This very likely could have been the case because the ridge between Meriwether and Mann Gulch would cause a southerly wind to form a vortex on the lee side in perfect position

to loft numerous firebrands and carry them to the north side of Mann Gulch. Gisborne later died near the gulch while attempting to resolve this issue.

The approximate locations of the spot fires at 5:30 are shown in figure 1. The crew turned around at about 5:45 when they found their route to the river blocked by the fire below them. On the map, their turnaround is designated point 1. In Maclean's book, the turnaround is designated point 6.

THE RACE THAT COULDN'T BE WON

The spot fires, which had started in heavy surface fuels, would have become intense, with flames extending into the tree crowns and climbing the tree boles. The tree crowns would have caught fire, and the strong gusty winds would have pushed the fire through the crowns. The crew could see a convection column of black smoke from the burning tree crowns between them and the Missouri River. The fire at this stage was burning in a stand of much denser forest than they were in farther up the gulch. Fuels in the area where the spot fires started were estimated to have been timber litter and live understory vegetation interspersed with accumulations of heavy dead and down woody material. For purposes of calculating fire behavior in the surface fuel, I estimated the fuel to be about equally divided between fuel models 10 and 12 (Anderson 1982). The moisture content of fine dead fuels during the hottest part of the day was calculated from the temperature and humidity to have been about 3.5 percent; the heavier fuels would not have been quite so dry. Although winds were strong (30 mi/h) in the open, the forest canopy would reduce windspeed under the trees. Using guides developed for fire behavior analysts (Albini and Baughman 1979; Rothermel 1983), the winds were estimated to have been about 5 mi/h at the midflame height of the fire in surface fuels (from 3½ to 5½ ft). The slope was estimated to be 44 percent in the area where the spot fires started.

The spread of the fire is derived first from the behavior of the surface fire. Under these conditions spot fires in the surface fuels would have produced an intense but relatively slow-moving fire, with an average spread rate of about 20 ft/min and flame lengths ranging between 7 and 11 ft. The fireline intensity in the surface fuels (fuels near the ground) would have been 400 to 1,000 Btu/ft·s. Given the strong winds, steep slope, and unstable atmosphere, the fire would have quickly crowned as described earlier. The wind-driven crown fire burning up the slope would have spread four to six times faster than the surface fire, or 80 to 120 ft/min.

Once the crown fire developed on the steep slope and was being driven by the turbulent winds, it would have spread at the faster rate of 120 ft/min. Maclean estimates the spot fires started about 400 yd from the turnaround, point 1. Fire behavior is difficult to assess when fires are just beginning, but if the spot fires started at about 5:30, the surface fires could have taken 10 min or so to spread slowly and develop into a running crown fire. At 120 ft/min the crown fire would spread 400 yd to point 1 in another 10 min, arriving there about 5:50, or 4 to 6 min after the crew had turned around and headed back up the gulch. Figure 2 shows the relative position of the crew and the fire from the time the spot fires started until the crew was overrun. The slope of the lines on the graph represents the rate of travel. The steeper the line, the faster the rate.

Foreman Dodge said the fire was 150 to 200 yd away from point 1 when the crew turned around. The surviving crew members, Rumsey and Sallee, recognized the danger and quickly moved up to stay close to Dodge.

As the crew moved back up the canyon, the timber began to thin. More grass and brush appeared in the understory. The crew may not have recognized the consequences of the fuel change. The lighter fuel would have produced a faster spreading fire. Other factors were also in the fire's favor. The fire was burning uphill with a following wind; the uphill grade slowed the crew, but it caused the fire to accelerate.

The crew continued hurrying across the slope along an 18 percent uphill grade. The survivors reported they traveled through tall grass much of the time. Grass would have been fully cured (dried out) by August 5 at this low elevation (3,600 ft). Fuel model 3, which represents cured tall grass, was used to calculate fire behavior from the point where the crew turned around (point 1) to the point where they were told to drop their heavy tools (point 2).

As the timber thinned, the fire would have been more exposed to the wind. We estimated midflame winds increased from 5 to about 7.5 mi/h in the thinner timber. We assumed the wind, although gusty and variable, was blowing in the same direction the crew was hurrying. The fire's rate of spread through the grass would have been about 170 to 280 ft/min, considerably faster than the 120 ft/min rate of spread as the fire approached point 1. In the grass, flame lengths would have reached 16 to 20 ft. Fireline intensity would have been 2,500 to 4,000 Btu/ft·s. The fire would still have been burning through the crowns, but since the trees were more scattered, the surface fire was probably moving ahead of the crown fire.

The distance from point 1 to point 2 is 450 yd, or 1,350 ft. At a spread rate of 170 to 280 ft/min, the fire would cover 1,350 ft in 5 to 8 min. Assuming the fire was spotting, the faster rate is probably more appropriate; the fire could have reached point 2 by 5:54.

After turning around at point 1, the crew went faster during each successive leg of the journey (fig. 2). But the fire went even faster.

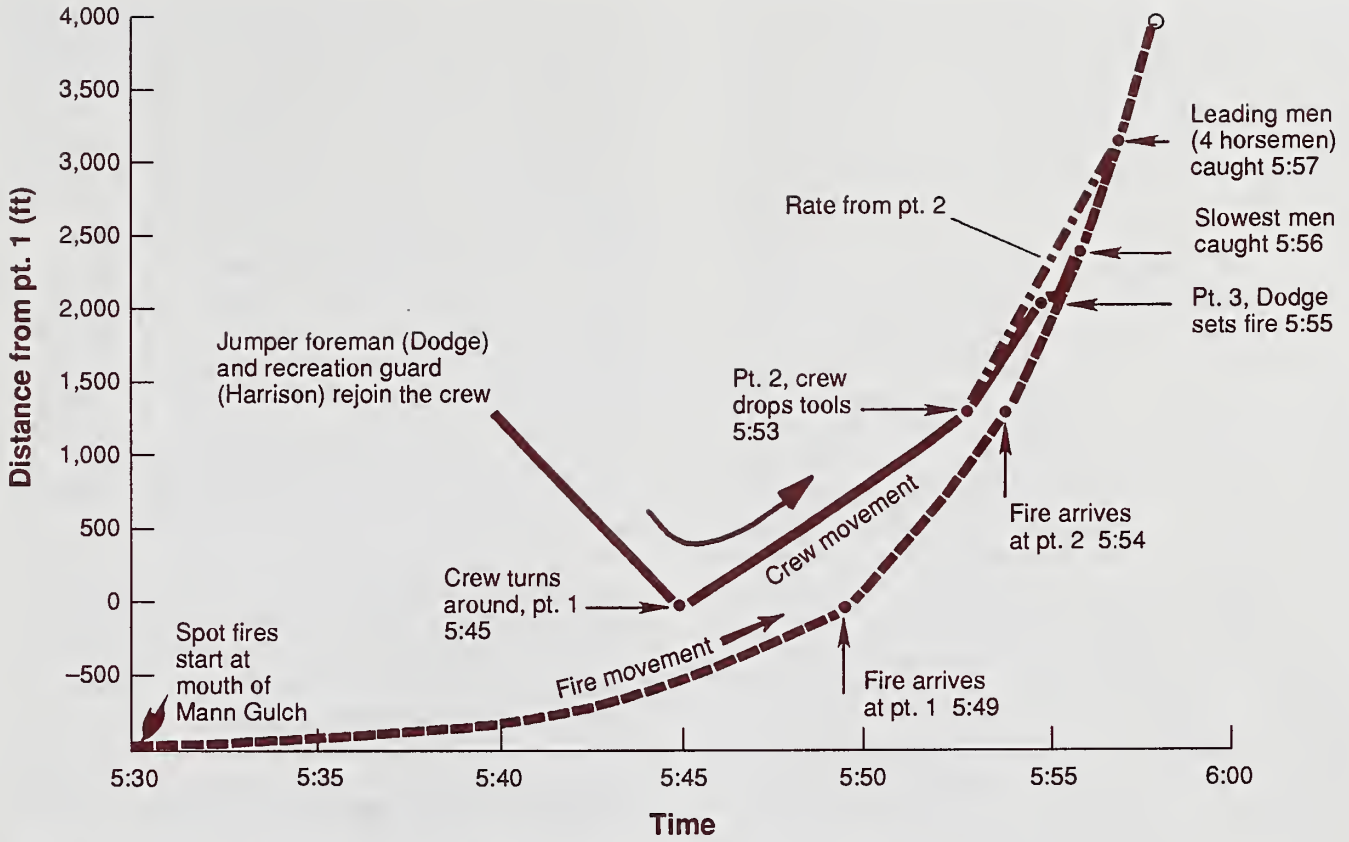

Figure 2—Distance and time graph of the estimated positions of the crew and the fire. Distances are estimated from the crew's turnaround at point (pt.) 1. The slopes of the lines indicate the rate of movement; the steeper the line, the faster the rate.

In hindsight, it's possible to ask why the crew didn't immediately beat the hastiest possible retreat as soon as fire blocked the route to the river. I suspect they did not yet realize how serious their situation had become. When they first saw fire blocking their route, the fire was probably in the early stages of development and had not yet begun to run. The crew did not have a trail to follow on this slope, which became as steep as 76 percent leading to the ridge on their left. They were sidehilling on a route with about an 18 percent slope. The terrain was broken and littered with loose rock. The river which they had set out to reach was now behind them, and there must have been some confusion about where they were going. It was very hot—Maclean believes it was much hotter than the 97 °F measured in Helena—and initially they were still carrying packs and tools. One crew member, Navon, was reported to have photographed the fire across the canyon, indicating they were not yet seriously concerned with escaping from the fire. Accounting for the time it took them to turn around and start up the gulch, they averaged 170 ft/min or about 2 mi/h over this leg of their retreat. I suspect they were going faster as they approached point 2.

At point 2, Dodge told his crew to discard their heavy tools. Most of the crew realized now that they were in real trouble. In his testimony, Dodge said that when the crew members dropped their tools, the fire was only 75 to 100 yd behind them. If the fire were traveling at 280 ft/min, it would cover that distance in about 1 min. Therefore, the crew would have reached point 2 about 1 min ahead of the fire, at about 5:53. The time it took them to go from point 1 to point 2 would have been about 8 min.

From point 2 to point 3, where Dodge lit the escape fire, conditions were similar to those from point 1 to point 2, except that the timber was even thinner. This allowed the wind near the surface to increase to an estimated 9 to 13 mi/h. Consequently, the fire's spread rate would have increased to somewhere between 360 and 610 ft/min. Flame lengths in the surface vegetation would have been 24 to 30 ft, with the flames from crowning trees reaching much higher. Fireline intensities from the surface fuel alone would have been between 5,500 and 9,000 Btu/ft·s.

The most pernicious effect of the crew's retreat up the canyon was that they had moved out of the timber into open areas more exposed to the wind. Carl

Wilson (1977) at the Riverside, CA, fire laboratory found that most fire fatalities have occurred in flashy fuels or on the periphery of larger fires. Fires spread rapidly in light fuels and can change direction and accelerate quickly as the wind shifts. Ironically, the crew did not reduce their danger when they moved into lighter fuels; in fact, the fire would have accelerated in the lighter, flashier fuels, especially as the surface wind became stronger. The acceleration is reflected in the increasingly steep lines of figure 2.

Based on the testimony of survivors Sallee and Rumsey, the crew may have broken up after dropping their tools at point 2. The official report states all tools were found within a 100-ft circle, so the crew was together at that point. Sallee said that Navon, a former paratrooper who fought with the 82nd Airborne Division in World War II, could be seen up the slope ahead of the crew. Others may already have joined him, because the final position of the bodies showed four crew members traveled much farther than the others. In his book, Maclean describes these men as the "four horsemen." From this point, the analysis is divided into two sections: the first describes the circumstances of the crew members whose bodies were found close to Dodge, and the second describes the four horsemen.

From point 2, where the crew dropped their tools, to point 3, where Dodge lit the escape fire, is about 240 yd; if the fire were spreading from 360 to 610 ft/min, it could have covered the distance in 1 to 2 min. Its arrival time at point 3 would have been between 5:55 and 5:56. If the slowest members died at about 5:56, as indicated by Harrison's broken watch, the estimated time of the fire's arrival is reasonable. We can set the time that the main fire overran Dodge's escape fire at about 5:55:30.

This estimate is consistent with Dodge's statement that the main fire was only 50 yd away when he stopped to light his escape fire. The main fire could cover 50 yd in 15 to 30 s if it were spreading from 360 to 610 ft/min. If the men near Dodge died at 5:56, when Harrison's watch stopped, then Dodge and those with him arrived at point 3 where he lit his fire at about 5:55.

The crew took 2 min to go from point 2 where they dropped their tools to point 3. They covered 240 yd or 720 ft, an average speed of 360 ft/min or about 4 mi/h. This is a very fast pace, considering the steep slope, poor footing, high temperatures, and the distance they had already traveled. One man was reported to have collapsed before reaching point 3. He had to be urged to continue.

The official report describes the fuels at point 3 and beyond as cheatgrass and fescue. I assumed that the fuels were equally represented by fuel models 1 and 3. Model 1 is lightly loaded fuel that describes cheatgrass very well; model 3 is a heavier grass model that should account for the fescue, weeds, and brush in the area. The fuel moisture was close to 3 percent, a very low value. Probably the most dangerous influence was the wind that may have been gusting to 40 mi/h in the open. It was probably scouring close to the ground, giving midflame winds of 15 to 20 mi/h. With these conditions, the fire would have spread between 600 and 750 ft/min, averaging 660 ft/min, with flames ranging from 10 to 40 ft long. The fireline intensity would have ranged very widely from about 850 to nearly 16,000 Btu/ft·s. The fire would have been characterized by extremely rapid spread, with pulsing flames that would rise and fall as the buoyancy of the rising heat and force of the wind competed. The light fuels would have burned out quickly, leaving small pockets of bunchgrass or heavier stems to continue burning as the fire raced ahead. The high temperatures of the flames, 1,500 to 1,800 °F, would be lethal, primarily because they would damage the respiratory system.

When the crew emerged from the trees into the grass at point 3, Dodge must have realized they could not reach safety and conceived the idea of burning away a small clearing. This escape fire, as it has come to be called, would quickly clear an area where the crew could go, after the fine fuels burned away, giving them a chance to escape the flames of the main fire.

Dodge sized up the situation better than most of his crew, who either thought they could outrun the fire or saw no other alternative. Some if not all of the crew stopped briefly to see what Dodge was doing and listen to his pleas for them to get into the burned-out area he was preparing. Someone is reported to have said: "To hell with that, I'm getting out of here!" No one stayed with Dodge. The crew members split up afterward, with the majority continuing to run up the canyon. I estimate they delayed no longer than 15 s at point 3, probably not that long. Some traveled on the contour and others went slightly downhill. The slowest of the crew members only got about 100 yd before being caught by the fire. One man broke his leg while fleeing on the steep, rocky slope.

The fire could have covered 100 yd in less than a minute at its calculated rate of 600 to 750 ft/min. Dodge estimated the men were caught in 30 s. If they had a 15-s lead on the fire after leaving him and traveled 100 yd before being caught 45 s later, they would have been running about 400 ft/min or 4½ mi/h, a little faster than they were running when they approached Dodge at point 3.

The four horsemen, who were found 375 yd beyond Dodge, may not have been with him when he started his fire. We can examine how fast they would have had to run to end up 375 yd beyond point 3, starting at either point 2 or point 3. From point 2 where the men dropped their tools to where the four horsemen died is 620 yd. If they were at point 2 at 5:53, the fire, according to my estimate, would have caught them at about 5:57, just a minute or so after it caught the

slower members. They would have had to have run 462 ft/min or 5¼ mi/h from point 2—an incredible pace on that slope. If they had been with Dodge and paused 15 s to catch their breath and watch him start the escape fire, they would have left him at 5:55. They would have had to run 375 yd in about 2 min, a pace of 562 ft/min or 6½ mi/h. That is a jogging pace of about 9 min/mi; such a pace could be sustained on a level surface, but would be all but impossible to maintain for 375 yd in heat and smoke on an uphill slope with rocks and grass underfoot. Both scenarios would have required extreme effort. Since both were possible, we cannot say whether the four horsemen were with Dodge when he lit his fire. But the comparisons indicate that they probably were not.

Much of what happened in the final moments probably cannot be explained simply by the fire catching up to the firefighters. Firebrands may have been falling among them, starting new fires. They could have continued running for some time, even after the fire caught them and was burning sporadically around them. Having said this, I still believe figure 2 illustrates the general course of events, even though it may not be precisely accurate. We see the crew increasing their pace, but the fire accelerates even faster until the lines converge—the end of a race the firefighters could not win.

THE SURVIVORS

Three smokejumpers survived uninjured: Dodge in his escape fire and Sallee and Rumsey, who took the shortest but steepest route directly up the slope to the ridge top.

One of the fascinating features of the Rocky Mountains is the rock formation known as "rimrock" (fig. 3). It appears as a wall of rock along the rims of canyons or around the top of flat mountains known as buttes. Rimrock is nearly perpendicular, varying in height depending on how much material has sloughed away. In Mann Gulch the rimrock is 6 to 12 ft high, broken occasionally by crevices.

When Dodge lit the escape fire, a curious thing happened: the low-intensity grass fire he started did not run before the main fire that was being driven up the canyon by strong winds. According to Sallee, Dodge's fire spread directly up the slope to the left of the route the crew had been traveling toward the rimrock, as shown in figures 3 and 4. This behavior is contrary to normal expectations. One explanation could be that the convection column of the main fire was directly overhead when Dodge lit his escape fire. For a very short time the convection column could have blocked the driving wind and the indrafts would have been pulled upward into the convection column. During this time, air movement would have been vertical rather than horizontal, producing a momentary calm. Such a calm period could have been established periodically as the fire spread in surges. Turbulent flames and fire whirls would reestablish themselves between such momentary periods of calm. Dodge is reported to have lit his fire with book matches, further evidence of a momentary period of calm, since such matches are notoriously poor for sustaining a flame in a wind.

Dodge's grass fire would have spread up the slope if there were no wind to drive it up the canyon with the main fire. Consequently, as reported, it would have spread up the side of the gulch to the north toward the rimrock.

Since the crew did not understand why Dodge was firing the grass, no one stayed with him. Sallee and Rumsey thought Dodge had set a fire that would somehow shield them from the main fire. These two men, along with another jumper, scrambled up the right-hand side of Dodge's fire to the base of the rimrock (fig. 4). Maclean estimates this distance to be 100 to 140 yd. Fortunately, Sallee and Rumsey found a crevice in the rimrock through which they climbed to the relative safety of the ridge above. Here Rumsey collapsed in a juniper bush, too exhausted to move until Sallee roused him out. They took refuge in a rockslide nearby. The third jumper, who followed the pair to the base of the rimrock, did not go through the crevice to the ridge above; his body was found at the base of the rimrock a few hundred feet away.

The squad boss Hellman also ran toward the rimrock, but he went up the left side of the escape fire, putting him between the main fire and the escape fire (fig. 4). He was caught somewhere near the crevice in the rimrock. Although he made it over the top, he died from his burns the next day.

Dodge lay down within the area he had burned off. The grassy slope quickly burned away, giving him a large area free of fuels to prevent the main fire's flames or radiation from injuring him. Dodge said fierce winds lifted him off the ground three times during the few minutes it took the fire to pass over him (C. E. Hardy, personal communication). At 6:10 Dodge was able to sit up and move about between the pockets of fire that were still burning.

SURVIVING, THEN AND NOW

On August 29, 1985, 73 firefighters were forced into cleared safety zones while fighting the Butte fire on the Salmon National Forest near Salmon, ID. They took refuge in their individual fire shelters for 1 to 2 h while a very severe crown fire burned around them. The Butte fire was part of the Long Tom fire complex (Rothermel and Mutch 1986). Only five firefighters needed to be hospitalized for heat exhaustion, smoke inhalation, and dehydration; the others were not injured. Investigators estimated that without the

Figure 3—Mann Gulch 2 weeks after the 1949 fire. The firefighters' route from their landing site to Dodge's fire is shown by the dashed line.

protection of the safety zones and the reflective fire shelters now carried by all firefighters, at least 60, if not all, of the firefighters would have died. Thanks to preparation of safety zones, the effectiveness of the fire shelters (Jukkala and Putnam 1986), and the sensible behavior of the firefighters themselves, disaster was averted.

Crews caught in the Butte fire survived a crown fire in continuous timber, a fire that was much more intense than the grass fire that killed firefighters at Mann Gulch. The crews on the Butte fire were forced to stay in their fire shelters for 1 to 2 h, while Dodge survived without a shelter and was able to move around after lying on his face for about 14 min. Nevertheless, the

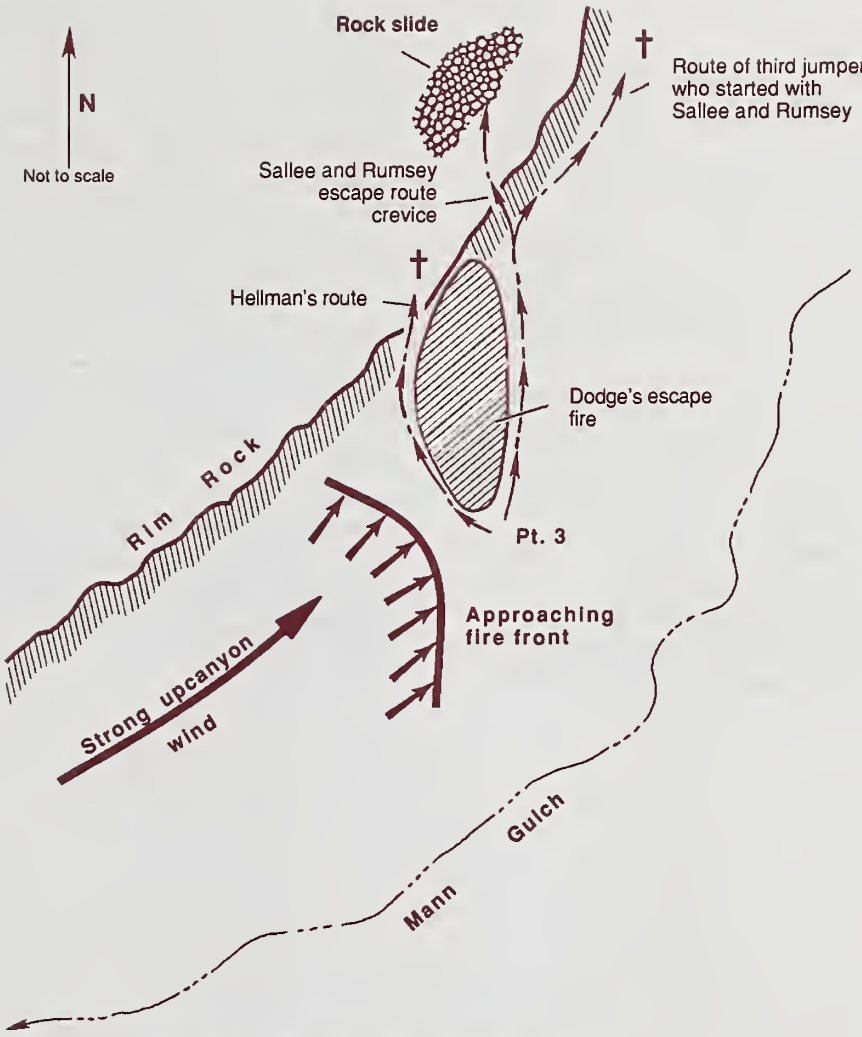

Figure 4—The paths of crew members who fled around the escape fire Dodge ignited at point (pt.) 3. Sallee and Rumsey survived; Hellman did not.

Mann Gulch fire was more intense than anyone could survive without some relief from the direct heat of the flames.

The crews on the Butte fire could not have survived without safety zones, larger than football fields, that had been cleared before they were needed and were within easy reach. Individual fire shelters protect the person inside from radiant heat and smoke, but cannot withstand sustained contact with flames.

In addition to the fire shelters developed since the Mann Gulch fire, the crews on the Butte fire had the benefit of survival training. In one instance, a bulldozer operator who had not had the survival training was pulled from his machine and placed within a shelter. For his actions in saving the operator's life, Brad Dougherty, a member of the Flamingo prison crew, received a reward for heroism.

The Butte fire crews had well-trained leaders who directed their crews to deploy shelters when it became necessary and moved them from hotter to cooler areas as the fire burned around them. The crews were well disciplined; no one attempted to run from the fire. They stayed together and followed orders even though they were badly frightened. Radio communication was maintained with the crews, lending reassurance. The firefighters at Mann Gulch did not have the benefit of a radio, since it had been broken during the cargo drop.

It should be kept in mind that Dodge's crew was conducting initial attack while the Butte fire crews were part of a large suppression organization that had been on the fire for some time. Nevertheless, these two incidents show some of the progress in preparing for and dealing with possible fire entrapments. While such progress is reassuring, we must continually strive for firefighter safety.

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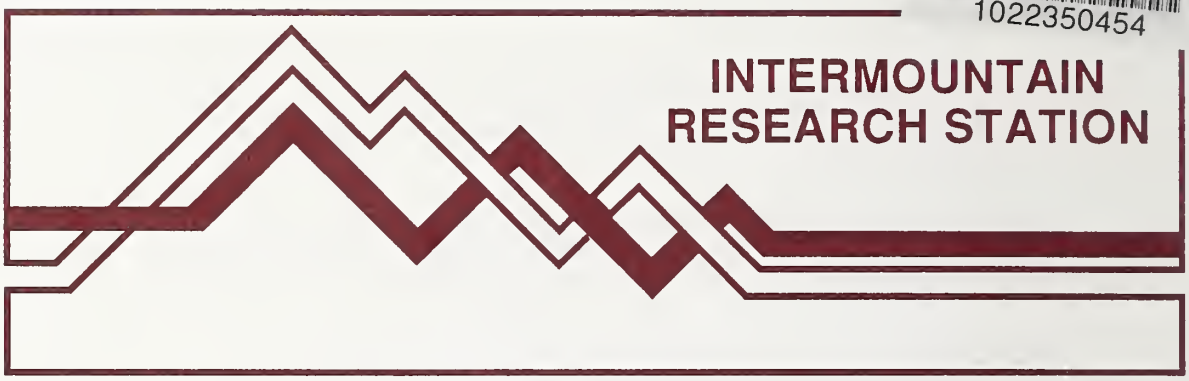
Describes the final 20 minutes of a smokejumper fire-fighting crew and the fire that overran 16 men as they were attempting to escape. The foreman and two firefighters escaped. Comparison with the behavior of a crew trapped by a fire in 1985 is described.

KEYWORDS: fire fighting, smokejumpers, fire behavior, safety, accidents



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